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CHLORIDE PENETRATION COEFFICIENT AND FREEZE-THAW DURABILITY OF WASTE METAKAOLIN CONTAINING HIGH STRENGTH SELF-COMPACTING CONCRETE

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Scope of the work

- Traditional ordinary concrete testing methods are still applied to characterize self-compacting concrete (SCC), however they are still under question due to superior properties of SCC.;
- Fast and progressive test methods should be selected and adapted which could effectively characterize SCC;
- Durability of SCC increases comparing to ordinary concrete therefore standard testing methods offer are not effective to characterize durability properties of SCC;
- Chloride penetration test method and freeze-thaw resistance test was evaluated as fast and reliable test method of SCC.

Aim of the work

To test chloride penetration coefficient and freeze-thaw durability of waste metakaolin containing high strength self-compacting concrete

Work tasks:

- Design the mixture composition of SCC and replace cement with waste metakaolin microfiller 5; 10 and 15% respectively;
- Perform the compressive strength tests at the age of 7, 28 and 180 days.
- Determine the chloride penetration coefficient according to NT BUILD 492
- Test freeze-thaw resistance according to LVS 156-1:2009 annex C.

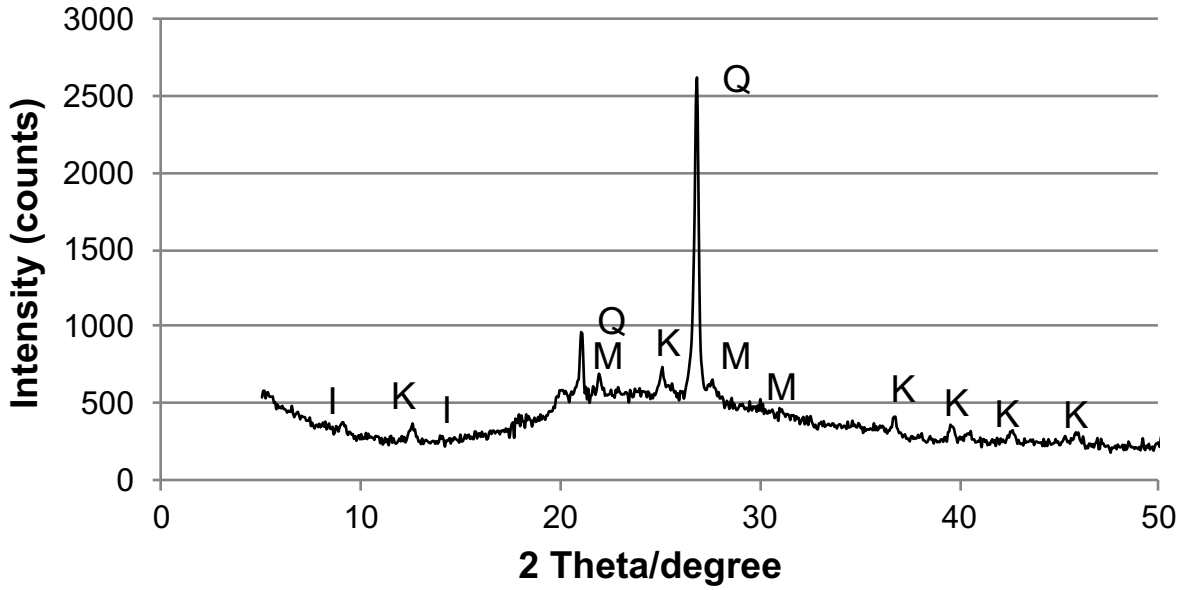
Mixture design

Mixture composition of self-compacting concrete

Compound	Amount (kg/m³)			
	REF	5%MKW	10%MKW	15%MKW
Cement CEM I 42.5 N (Cemex)	500	475	450	425
Sand 0/4 mm	700	700	700	700
Quartz sand 0/0.3 mm	118	118	118	118
Gravel 4/12 mm	908	908	908	908
Water	190	190	190	190
Superplasticizer Sikament 56	4.0	4.0	4.6	4.8
Metakaolin containing waste	0	25	50	75
W/C	0.38	0.40	0.42	0.45
W/(C+MKW)	0.38	0.38	0.38	0.38

- Water to cement and MKW ratio was 0.38;
- To remain workability (cone flow >600 mm) the amount of superplasticizer was increased.

Metakaolin containing waste (MKW)



XRD pattern of metakaolin containing waste by-product (MKW). M – microcline, I – illite, K – kaolin, Q – quartz.

- MKW from foam glass granule production plant with fraction <0.355 mm was studied as pozzolanic material in SCC partially replacing cement.
- During production MKW was calcined at 850^{O}C for about 40-50 minutes.

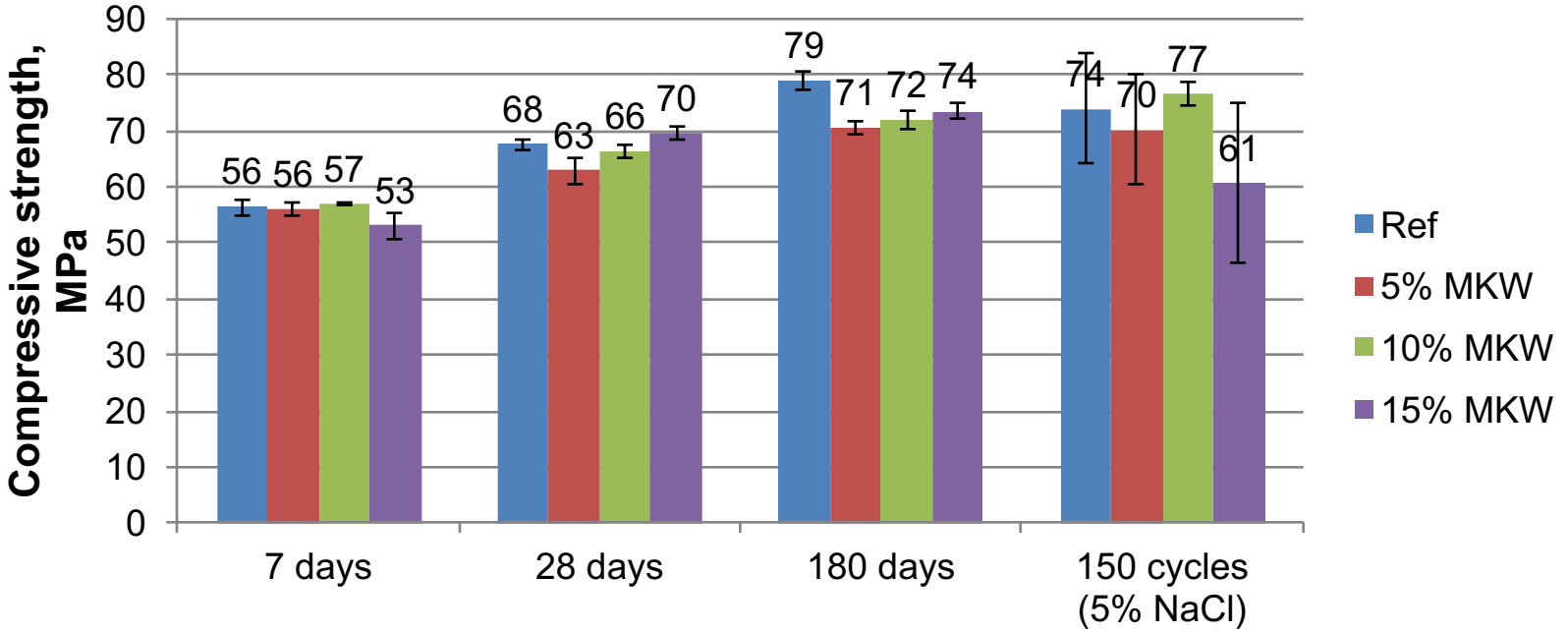
Results. Fresh concrete properties

Fresh self-compacting concrete properties

Mixture design	Fresh concrete density, (kg/m^3)	Flow time, (s)	Cone flow diameter, (mm)
Ref	2430	25	**630**
5%MKW	2410	25	**600**
10%MKW	2400	23	**680**
15%MKW	**2390**	**34**	**670**

- Up to 20% more superplasticizer must be used to ensure workability >600 mm for SCC with 15% MKW as partial cement replacement.
- The flow time of fresh SCC increased from 25 to 34 seconds.

Results. Hardened concrete properties

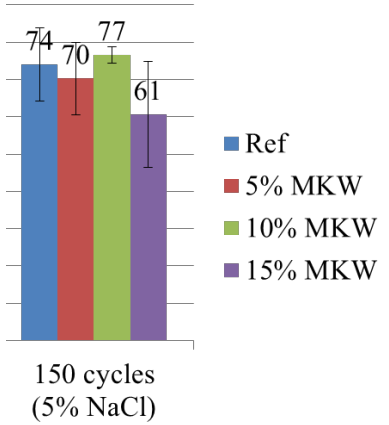


- 7d compressive strength was from 53-57 MPa which increased to 63-70 MPa at the age of 28d.
- Long term compressive strength (180 d) was from 71 to 79 MPa.
- Strength reduction after 150 freeze-thaw cycles in 5% NaCl deicing solution indicate strength reduction for all samples except 10% MKW

Durability. Freeze-thaw resistance

- According to LVS 156-1:2009 annex C: 150 freeze-thaw cycles in 5% NaCl deicing solution conforms to standard 500 freeze-thaw cycles (deicing in water);
- 6 cubical specimens 100x100x100mm are tested;
- After 150 freeze-thaw cycles compressive strength is tested and results mathematically evaluated;
- High value Standard deviation and variation coefficient indicates the retardation of concrete structure and compressive strength.

Mixture composition	500 freeze-thaw cycles				
	sn	dn	Vn	0.9*Xmin'	Xmin''
Ref	26,5	10,6	0,14	64,5	5,9
5% MKW	21,2	8,5	0,12	58,0	15,8
10% MKW	5,4	2,2	0,03	57,8	62,7
15% MKW	31,9	12,8	0,21	59,9	-21,4

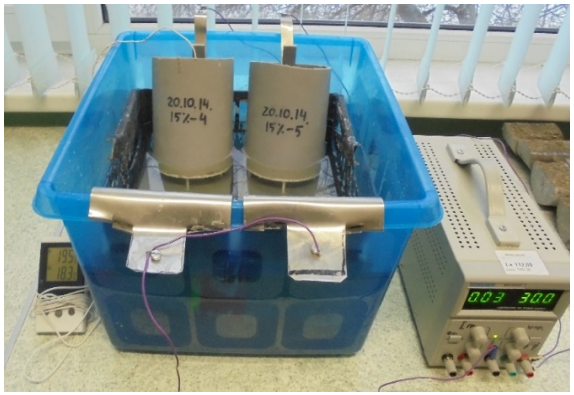


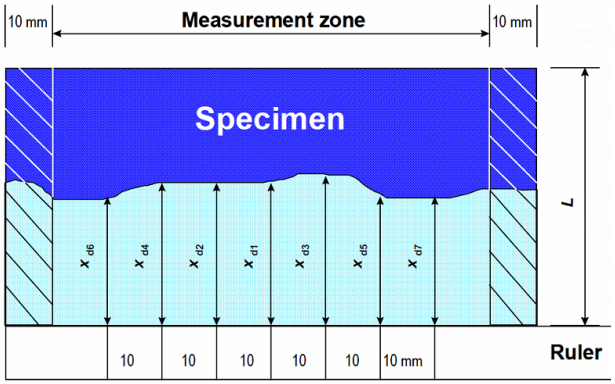
- Mixture composition with 10% MKW remained satisfactory concrete properties and could be evaluated as durable after 500 freeze-thaw cycles

- b)

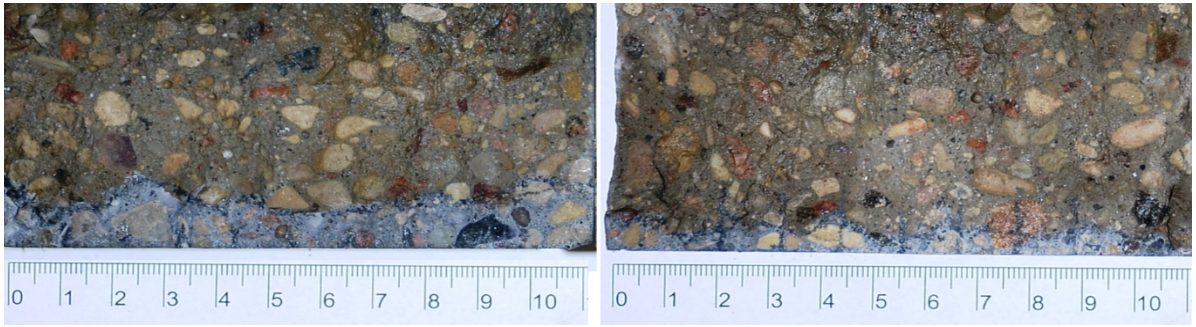
Durability. Chloride penetration test

Durability of the chloride penetration for SCC was performed according to NT BUILD 492. Three specimens with ⌀100 mm and height of 50 mm were created and tested.





The experimental setup of the test to determine the depth of chloride migration coefficient and the illustration of measurement for chloride penetration depths.



The depth of chloride migration in reference and 15% WMK.

Results. Chloride penetration test: non-steady-state migration coefficient D_{nssm}

Chloride penetration test results of SCC (non-steady-state migration coefficient)

Mixture design	D_{nssm} [$10^{-12}m^2/s$]	Standard deviation
Ref	7.70	0.37
5%MKW	5.41	0.11
10%MKW	3.63	0.12
15%MKW	2.08	0.03

- Incorporation of MKW in the mixture composition reduced D_{nssm} by 3.7 times compared to Ref.

SCC mixture composition 15%MKW could be evaluated as “very good” (D_{nssm} <$2 \cdot 10^{-12}m^2/s$) regarding to the resistance to chloride ingress while SCC with D_{nssm} <$8 \cdot 10^{-12}m^2/s$ has been evaluated as “good” resistance against chloride ingress [1].

[1] Edvardsen, C. and Jepsen, M. T., Chloride migration coefficients from non-steady-state migration experiments at environment-friendly ‘green’ concrete,” 2nd Int. Rilem Work. Test. Model. Chloride Ingress into Concr., 19 (2000). 203–209

Conclusions

- By replacing cement with MKW from 5 to 15 wt.%, the amount of superplasticizer must be increased from 15 to 20% to ensure the proper mix flow.
- The strength index of SCC with MKW at the age of 28 days was from 93 to 103% compared to reference SCC (63 to 70 MPa).
- The durability against chloride penetration was increased more than 3.7 times \ (D_{nssm}7.70 $10^{-12}m^2/s$ for Ref mix reduced to 2.08 for mixture with 15% MKW as partial cement replacement)
- NT BUILD 492 test method proved to be effective for testing and evaluating SCC chloride penetration durability.

Conclusions

- The freeze-thaw test results indicated that SCC durability up to 500 Standard freeze-thaw cycles could be obtained by incorporating 10% of MKW as partial cement replacement.
- Using 5% NaCl solution as deicing fluid, according to Standard LVS 156:2009 annex C, the required number of freeze-thaw cycles could be reduced to 150 cycles which still takes a long period of time for performing this test due to capacity of 1 cycle per 24 h.

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Thank you for your attention!